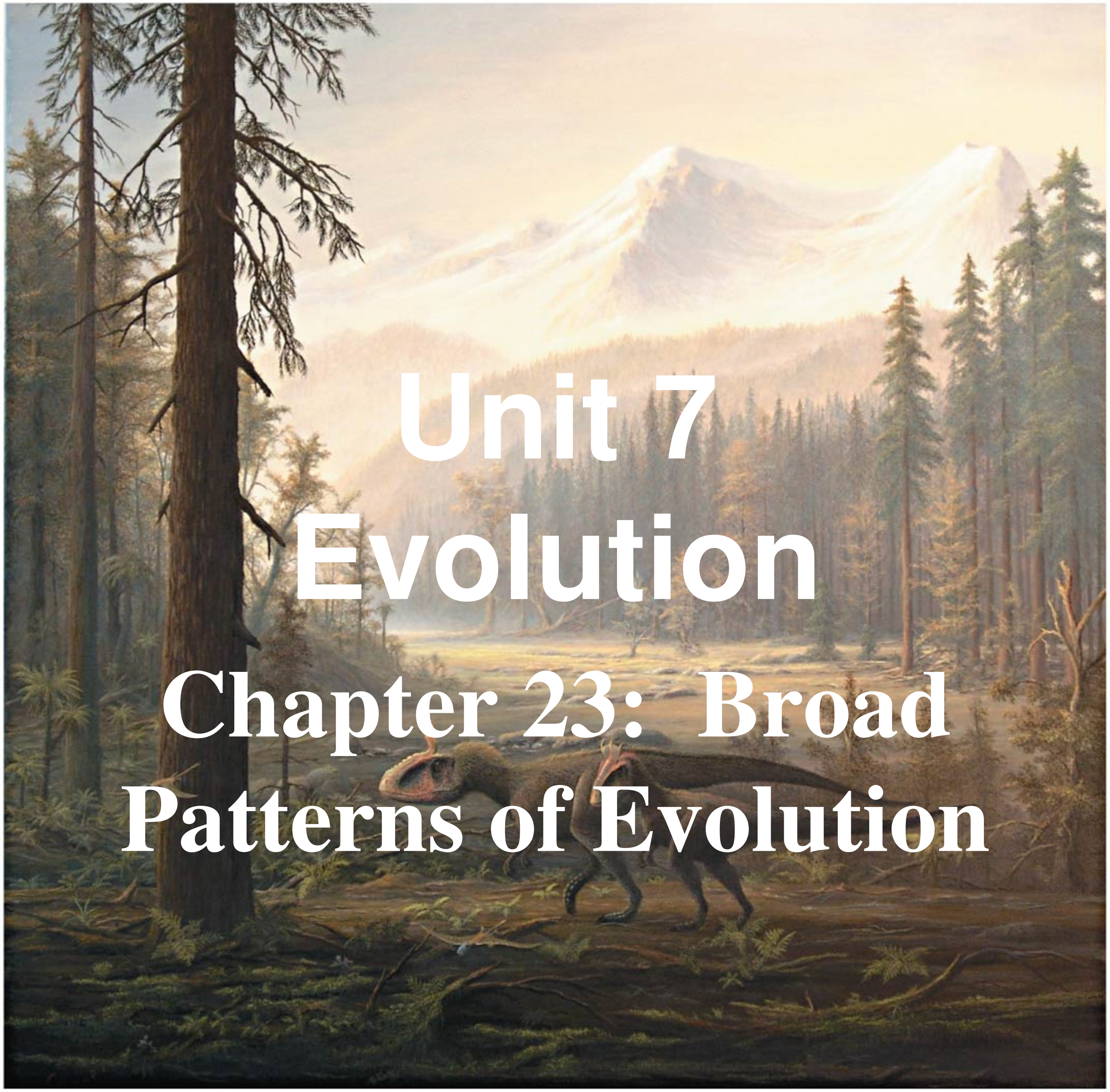


Unit 7 Evolution

Chapter 23: Broad Patterns of Evolution

Overview: Lost Worlds

- Past organisms were very different from those now alive
- The fossil record shows evidence of **macroevolution**
  - Broad changes above the species level
  - For example
    - The emergence of terrestrial vertebrates
    - The impact of mass extinctions
    - The origin of flight in birds

Concept 23.1: The fossil record documents life's history

- The fossil record reveals changes in the history of life on Earth
- Sedimentary rocks are deposited into layers called strata
  - Richest source of fossils
- The fossil record indicates that there have been great changes in the kinds of organisms on Earth at different points in time

The Fossil Record

- Few individuals have fossilized, and even fewer have been discovered
  - Incomplete chronicle of evolutionary change
- The fossil record is biased in favor of species that
  - Existed for a long time
  - Were abundant and widespread
  - Had hard shells, skeletons, etc.

How Rocks and Fossils Are Dated

- Sedimentary strata reveal the relative ages of fossils
- The absolute ages of fossils can be determined by **radiometric dating**
  - Based on the decay of radioactive isotopes
- A "parent" isotope decays to a "daughter" isotope at a constant rate
- Each isotope has a known **half-life**
  - The time required for half the parent isotope to decay
  - Not affected by temperature, pressure, or other environmental variables

Figure 23.3

Fraction of parent isotope remaining

Accumulating "daughter" isotope

½

Remaining "parent" isotope

¼

⅛

1⁄16

1 2 3 4

Time (half-lives)

- Fossils contain isotopes of elements that accumulated in the organisms when they were alive
- Radiocarbon dating can be used to date fossils up to 75,000 years old
- For older fossils, some isotopes can be used to date volcanic rock layers above and below the fossil

The Geologic Record

- The **geologic record** is a standard time scale dividing Earth's history into 4 eons and further subdivisions
- 4 Eons
  1. Hadean
  2. Archaean
  3. Proterozoic
  4. Phanerozoic eons
     - Encompasses most of the time that animals have existed on Earth

- The Phanerozoic is divided into three eras
  1. Paleozoic
  2. Mesozoic (age of reptiles)
  3. Cenozoic
- Major boundaries between geological divisions correspond to extinction events in the fossil record

- The oldest known fossils are **stromatolites**
  - Rocks formed by the accumulation of sedimentary layers on bacterial mats
  - Date back 3.5 billion years ago
- Prokaryotes were Earth's sole inhabitants for more than 1.5 billion years
  - Their production of oxygen led to extinction of some organisms and proliferation of others, like eukaryotes

The Origin of New Groups of Organisms

- Mammals belong to the group of animals called tetrapods
- The evolution of unique mammalian features can be traced through gradual changes over time
  - One lower jaw bone in mammals
  - 3 bones that transmit sound in middle ear
  - Differentiated teeth

Concept 23.2: The rise and fall of groups of organisms reflect differences in speciation and extinction rates

- The history of life on Earth has seen the rise and fall of many groups of organisms
- The rise and fall of groups depend on speciation and extinction rates within the group

Plate Tectonics

- At three points in time, the landmasses of Earth have formed a supercontinent
- According to the theory of **plate tectonics**, Earth's crust is composed of plates floating on Earth's mantle
- Tectonic plates move slowly through the process of *continental drift*
- Oceanic and continental plates can separate, slide past each other, or collide
- Interactions between plates cause the formation of mountains and islands and earthquakes

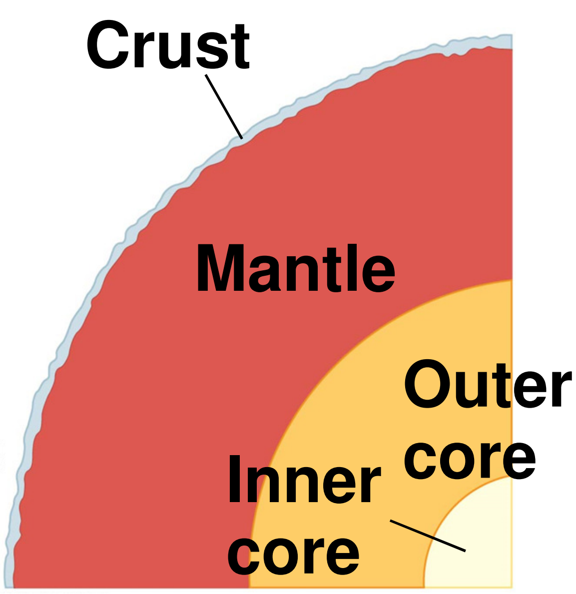
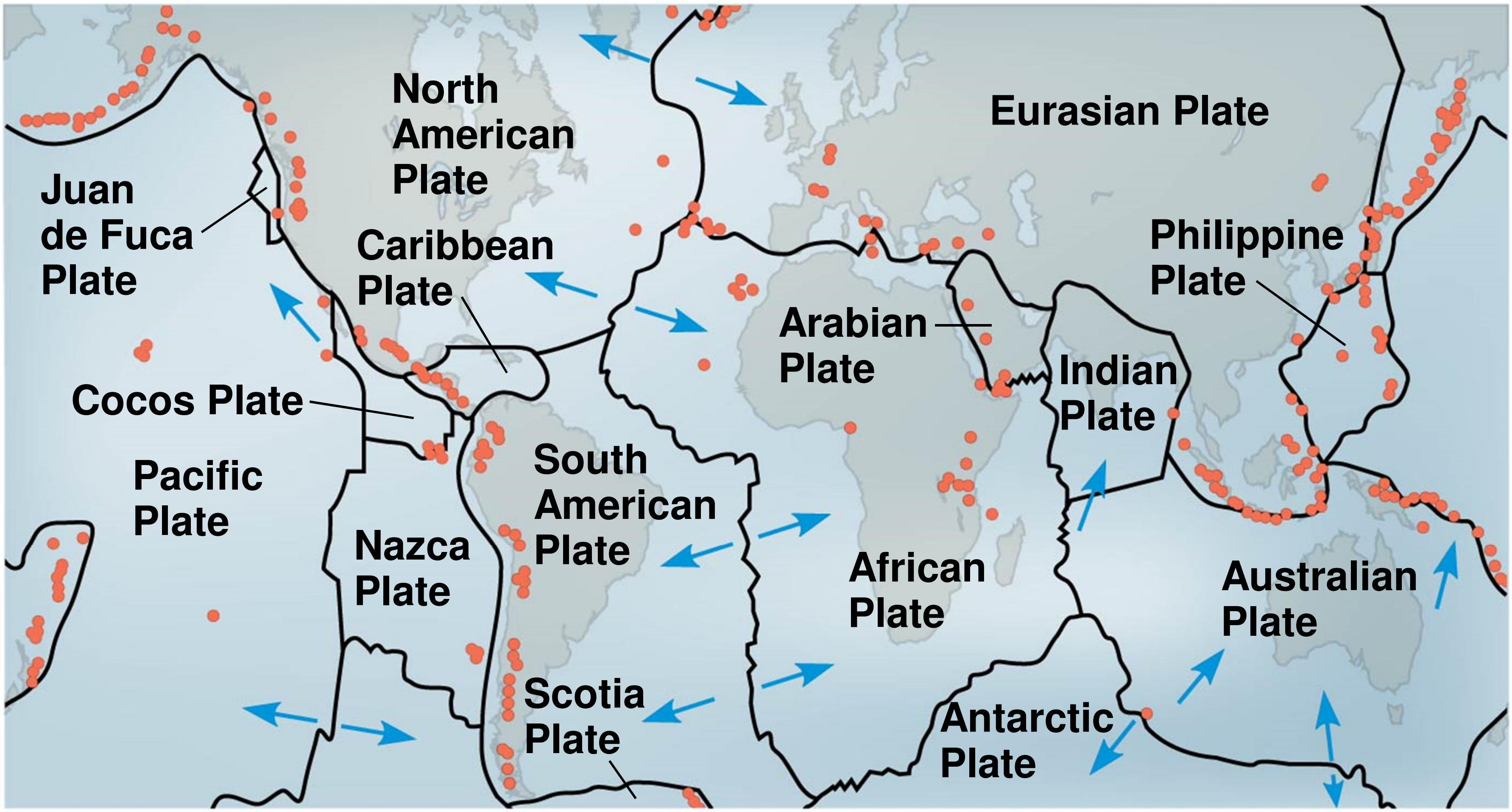


Figure 23.7

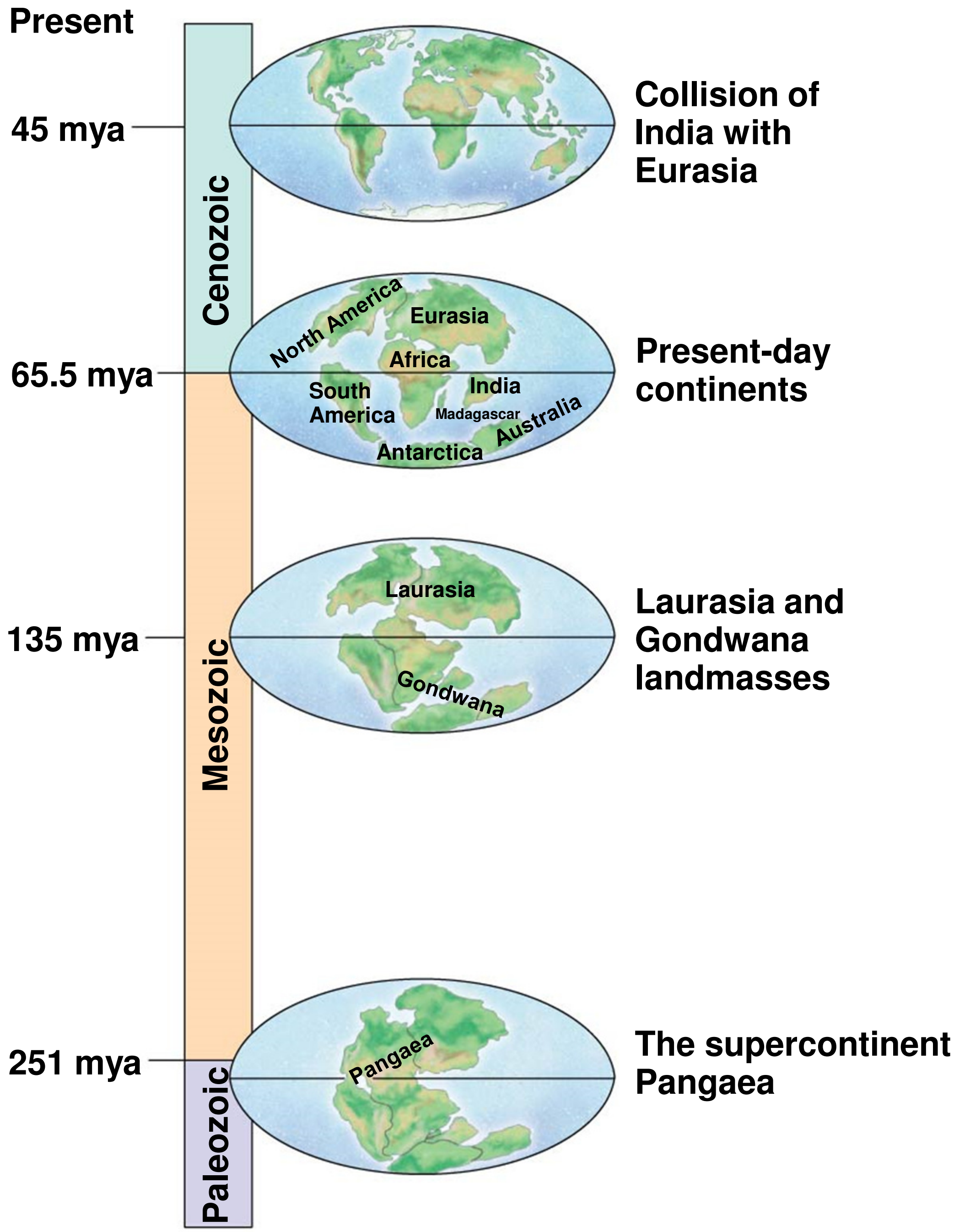


North American Plate
Eurasian Plate
Juan de Fuca Plate
Caribbean Plate
Philippine Plate
Arabian Plate
Indian Plate
Cocos Plate
Pacific Plate
South American Plate
Nazca Plate
African Plate
Australian Plate
Scotia Plate
Antarctic Plate

Consequences of Continental Drift

- Continental drift alters the habitats in which organisms live
- Formation of the supercontinent **Pangaea** about 250 million years ago had many effects
  - A deepening of ocean basins
  - A reduction in shallow water habitat
  - A colder and drier climate inland

Figure 23.8


Present
45 mya
65.5 mya
135 mya
251 mya
Cenozoic
Mesozoic
Paleozoic
Collision of India with Eurasia
North America
Eurasia
Africa
South America
India
Madagascar
Australia
Antarctica
Present-day continents
Laurasia
Gondwana
Laurasia and Gondwana landmasses
Pangaea
The supercontinent Pangaea

- Continental drift can cause a continent’s climate to change as it moves north or south
- Separation of landmasses can lead to allopatric speciation
- The distribution of fossils and living groups reflects the historic movement of continents
  - For example, the similarity of fossils in parts of South America and Africa is consistent with the idea that these continents were formerly attached

Mass Extinctions

- The fossil record shows that most species that have ever lived are now extinct
- Extinction can be caused by changes to a species' environment
- At times, the rate of extinction has increased dramatically and caused a **mass extinction**
  - Mass extinction is the result of disruptive global environmental changes

The "Big Five" Mass Extinction Events

- In each of the five mass extinction events, more than 50% of Earth's species became extinct
- A number of factors might have contributed to these extinctions
  - Intense volcanism
  - Global warming resulting from the emission of large amounts of CO_2 from the volcanoes
  - Reduced temperature gradient from equator to poles
  - Oceanic anoxia from reduced mixing of ocean waters
  - Meteorite and subsequent dust clouds

Is a Sixth Mass Extinction Under Way?

- Scientists estimate that the current rate of extinction is 100 to 1,000 times the typical background rate
  - Human actions, such as habitat destruction, are drastically modifying global environment
- Extinction rates tend to increase when global temperatures increase
- Data suggest that a sixth, human-caused mass extinction is likely to occur unless dramatic action is taken

Consequences of Mass Extinctions

- Mass extinction can alter ecological communities and the niches available to organisms
- It can take 5–100 million years for diversity to recover following a mass extinction
- The type of organisms residing in a community can change with mass extinction
  - For example, the percentage of marine predators increased after the Permian and Cretaceous mass extinctions
- Mass extinction can pave the way for adaptive radiations

Adaptive Radiations

- **Adaptive radiation** is the evolution of many diversely adapted species from a common ancestor
  - Many new species form whose adaptations allow them to fill different ecological roles (niches)
- Adaptive radiations may follow
  - Mass extinctions
  - The evolution of novel characteristics
  - The colonization of new regions

Worldwide Adaptive Radiations

- Mammals underwent an adaptive radiation after the extinction of terrestrial dinosaurs
  - The disappearance of dinosaurs (except birds) allowed for the expansion of mammals in diversity and size
- Other notable radiations include photosynthetic prokaryotes, large predators in the Cambrian, land plants, insects, and tetrapods

Regional Adaptive Radiations

- Adaptive radiations can occur when organisms colonize new environments with little competition
- The Hawaiian Islands are one of the world’s great showcases of adaptive radiation

Figure 23.15

Close North American relative, the tarweed *Carlquistia muirii*

Dubautia laxa

KAUAI 5.1 million years

MOLOKAI

1.3 million years MAUI

Argyroxiphium sandwicense

OAHU 3.7 million years

LANAI

N

HAWAII 0.4 million years

Dubautia waialealae

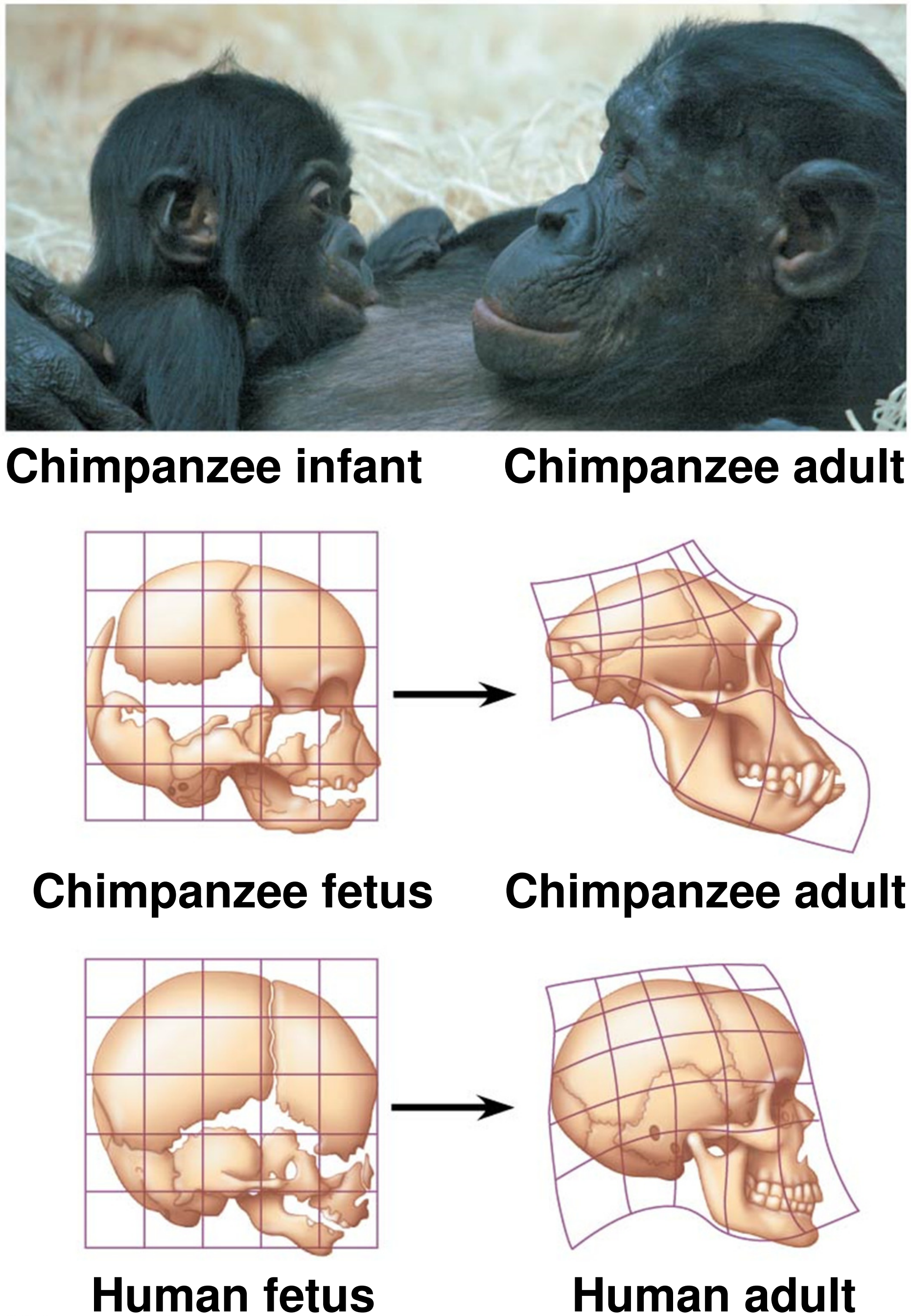
Dubautia scabra

Dubautia linearis

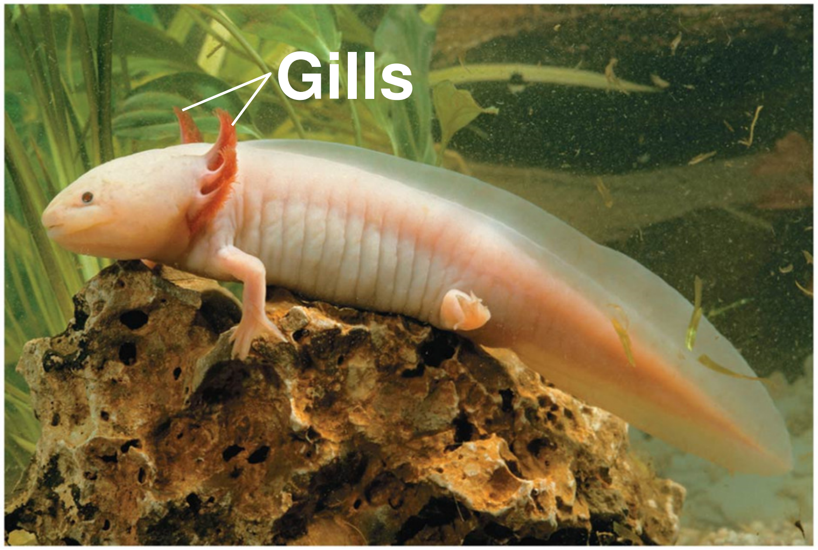
Concept 23.3: Major changes in body form can result from changes in the sequences and regulation of developmental genes

- Genes that program development influence the rate, timing, and spatial pattern of changes in an organism's form as it develops into an adult
- **Heterochrony** is an evolutionary change in the rate or timing of developmental events
  - It can have a significant impact on body shape
  - The contrasting shapes of human and chimpanzee skulls are the result of small changes in relative growth rates

Figure 23.16


Chimpanzee infant
Chimpanzee adult
Chimpanzee fetus
Chimpanzee adult
Human fetus
Human adult

- Heterochrony can alter the timing of reproductive development relative to the development of nonreproductive organs
  - In **paedomorphosis**, the rate of reproductive development accelerates compared with somatic development
  - The sexually mature species may retain body features that were juvenile structures in an ancestral species



Changes in Spatial Pattern

- Substantial evolutionary change can also result from alterations in genes that control the placement and organization of body parts
- **Homeotic genes** determine such basic features as where wings and legs will develop on a bird or how a flower's parts are arranged
  - *Hox* genes are a class of homeotic genes that provide positional information during animal development
  - If *Hox* genes are expressed in the wrong location, body parts can be produced in the wrong location
    - Ex: In crustaceans, a swimming appendage can be produced instead of a feeding appendage

The Evolution of Development

- Adaptive evolution of both new and existing genes may have played a key role in shaping the diversity of life
  - *Cambrian explosion*
    - Rapid diversification of animals
- Developmental genes may have been particularly important in this process
- Changes in morphology likely result from changes in the regulation of developmental genes rather than changes in the sequence of developmental genes

Concept 23.4: Evolution is not goal oriented

- Origin of new species has been affected by
  - Small scale factors, such as natural selection
  - Large scale factors, such as continental drift
- Evolution is like tinkering—it is a process in which new forms arise by the slight modification of existing forms
  - Has led to 3 key features of the natural world
    - Organisms that are suited to their environments
    - Shared characteristics of life
    - Diversity of life

Evolutionary Novelties

- Most novel biological structures evolve in many stages from previously existing structures
  - Complex eyes have evolved from simple photosensitive cells independently many times
- Natural selection can only improve a structure in the context of its current utility

Evolutionary Trends

- Extracting a single evolutionary progression from the fossil record can be misleading
  - Apparent trends should be examined in a broader context
- The species selection model suggests that differential speciation success may determine evolutionary trends
- Evolutionary trends do not imply an intrinsic drive toward a particular phenotype
- Evolution is the result of interactions between organisms and their current environments
  - If environmental conditions change, an evolutionary trend may cease or even reverse